

# Radiative Enhancement Effects on Flame Spread (REEFS) Project Studied “Green House” Effects on Fire Spread

The Radiative Enhancement Effects on Flame Spread (REEFS) project, slated for flight aboard the International Space Station, reached a major milestone by holding its Science Concept Review this year. REEFS is led by principal investigator Paul Ronney from the University of Southern California in conjunction with a project team from the NASA Glenn Research Center. The study is focusing on flame spread over flat solid fuel beds to improve our understanding of more complex fires, such as those found in manned spacecraft and terrestrial buildings. The investigation has direct implications for fire safety, both for space and Earth applications, and extends previous work with emphasis on the atmospheres and flow environments likely to be present in fires that might occur in microgravity. These atmospheres will contain radiatively active gases such as carbon dioxide (CO<sub>2</sub>) from combustion products, and likely gaseous fuels such as carbon monoxide (CO) from incomplete combustion of solid fuel, as well as flows induced by ventilation currents.

During tests in the 2.2-Second Drop Tower and KC-135 aircraft at Glenn, the principal investigator introduced the use of foam fuels for flame spread experiments over thermally thick fuels to obtain large spread rates in comparison to those of dense fuels such as PMMA. This enables meaningful results to be obtained even in the 2.2 s available in drop tower experiments.



*Front-view image of flame spread over a thick, 10-cm-wide solid fuel bed. Flame spreads toward the bottom of the image. The bright band in the lower part of the images is the flame front; the upper bright band is from the ignition source. Top: Microgravity. Bottom: Earth gravity.*

Thick-fuel flame spread experiments using foam fuels gave indications that, in contrast to conventional understanding, steady spread can occur over thick fuels even in quiescent microgravity environments, especially when a radiatively active diluent gas such as  $\text{CO}_2$  is employed, as the principal investigator had hypothesized. As with thin fuels, the spread rates at microgravity can even exceed those at Earth gravity when a radiatively active diluent gas is used. Measurements of radiative emission from  $\text{O}_2/\text{CO}_2$  atmosphere tests in microgravity revealed that there is substantial emission, absorption, and reemission. Hence, it was shown that the faster flame spread rates are due to radiative transfer from

the flame to the unburned fuel surface (the "green house" effect) and that this heat transfer enhancement can lead to steady spread even when conductive heat transfer from the flame to the fuel bed is negligible.

These findings are particularly noteworthy considering that the International Space Station employs CO<sub>2</sub> fire extinguishers; the results suggest that helium may be a better fire suppressant/extinguishing agent on both mass and mole bases in microgravity even though CO<sub>2</sub> is much better on a mole basis in Earth gravity.

REEFS plans to use the FEANICS (Flow Enclosure Accommodating Novel Investigations in Combustion of Solids) insert that will go into the Combustion Integrated Rack facility on the International Space Station. FEANICS is a generically designed flow tunnel for solid fuel and spacecraft fire safety combustion experiments conducted by several investigators.

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